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AIR QUALITY STUDIES
in the vicinity of the
ONTARIO HYDRO THERMAL GENERATING STATION
ATIKOKAN
1981

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INTRODUCTION

Ontario Hydro began construction of a 200-megawatt thermal generating station near Atikokan in January, 1978. Concerns were expressed about the effects of airborne emissions from this plant on ecologically sensitive areas such as Quetico Provincial Park in Ontario, and the Boundary Waters Canoe area and Voyageurs National Park in northern Minnesota. In cooperation with Ontario Hydro and the Ontario Ministry of Natural Resources, a comprehensive environmental monitoring program began in 1979. The Ontario Ministry of the Environment was responsible for vegetation, soil and snow sampling. Baseline sampling of forest vegetation and soil commenced in 1981, with the intention of obtaining 3 years of background data before the scheduled start-up of the power plant in 1984. While this report is concerned mainly with vegetation and soil studies, a brief summary of air quality data obtained by Ontario Hydro is also included.

METHODS

Vegetation and soil sampling sites were selected in May, 1981. Factors considered in site selection were: prevailing wind direction, distance from the power plant, access, proximity to air quality and precipitation sampling sites, and presence of suitable vegetation. Study sites (Figure 1) were established on islands or shorelines of lakes and were oriented to obtain maximum possible exposure to airborne contaminants emitted from the generating station. Following standard Ministry procedures (1), we collected samples of foliage from white birch (*Betula papyrifera*), current and one-year-old white pine (*Pinus Strobus*), beaked hazel (*Corylus cornuta*), mountain maple (*Acer spicatum*) and willow (*Salix* spp.) from as many as possible of the 14 sites. Not all species were present at each location. We also sampled feather moss (*Pleurozium schreiberi*), a foliose lichen

(Umbilicaria muhlenbergii) and three depths of soil (0-1, 1-2, 2-5 centimetres (cm)). Bark samples were obtained at a height of 1 to 1.5 m (metres) from stems of white pine trees sampled for foliage. All bark samples were collected from the sides of trees facing the power plant. Trees and shrubs were tagged for sampling in future years. All samples were analysed for aluminum, arsenic, cadmium, chloride, chromium, copper, fluoride, iron, lead, mercury, manganese, nickel, sodium, sulphur and zinc at the Ministry's laboratories in Thunder Bay and Toronto. In addition, soils were analysed for calcium, magnesium, phosphorus, potassium, and the pH of soil and bark was determined. Samples of dried Sphagnum moss in open-mesh polypropylene bags (2) were exposed from May 25 to July 29, 1981, at all study sites. Moss from this experiment was analysed for the same parameters as tree and shrub vegetation.

Vegetation in the vicinity of designated study locations was examined for visible evidence of stress caused by diseases, insects, contaminants or physiological factors.

RESULTS

VEGETATION AND SOIL

Tree and Shrub Foliage

Vegetation in the survey area was found to be free of noteworthy insect or disease problems. Minor insect defoliator injury was noted on trembling aspen, white birch, willow and beaked hazel. Chemical analysis results are summarized in Table 1. Foliar levels of all parameters were within expected background ranges at all sites. The occurrence of generally higher element concentrations in one year-old pine foliage than in current foliage is considered normal. The highest arsenic levels in one year-old pine foliage occurred at sites 1, 4 and 11, near two former iron ore mines.

White Pine Bark

Elevated levels of arsenic and iron were found in white pine bark at several sites, as shown in Table 2. This contamination represents historical deposition of airborne pollutants emitted by two iron ore mines and pelletizing plants which operated for many years (until 1980) near the present power plant site.

Lichen and Moss

For the same reasons outlined above, levels of arsenic and iron in feather moss and Umbilicaria lichen were also much higher near the generating station than in outlying areas (Table 2). The distribution of these elements in feather moss, plotted in Figure 2, was similar to that for Umbilicaria lichen and pine bark.

Data from the moss exposure experiment (Table 3) revealed that all parameters were low and within the range considered normal. This finding indicates that the elevated arsenic and iron in feather moss, lichen and pine bark is due to historical rather than current contamination.

Soil

Soil analysis results are summarized in Table 4, with detailed values for arsenic and iron in Table 5. Arsenic and iron were generally highest in surface soils near the former iron ore operations (Figures 3a and 3b). Here, arsenic and iron concentrations usually decreased as soil depth increased. For the other parameters, there was no apparent trend in relation to soil depth and distance from former pollution sources. Soil pH levels were all within the range considered normal for the area.

AIR QUALITY MONITORING

Sulphur Dioxide (SO_2)

A summary of readings obtained from Ontario Hydro's five-station network (Figure 4) are presented in Table 6. At the four

sites in operation during 1981, SO_2 levels never approached the provincial air quality objectives of 250 ppb (parts of sulphur dioxide per billion parts of air, 1-hour average) or 100 ppb (24-hour average). Concentrations were typical of normal background values expected in areas remote from pollution sources.

Nitrogen Oxides (NO_x)

Monitoring for oxides of nitrogen began at Nym Lake in mid-October, 1981. For the last 2½ months of the year, all concentrations were normal. The maximum 1-hour reading was 60 ppb, compared to the maximum acceptable limit of 200 ppb. Similarly, the maximum 24-hour concentration was well below the objective of 100 ppb.

Ozone (O_3)

No ozone results are available for 1981.

Total Suspended Particulate Matter (TSP)

Available data for the period May 16 to December 31, 1981, at Ontario Hydro's Nym Lake monitoring station show that, in 35 samples, concentrations of TSP never exceeded the Ministry's 24-hour objective of 120 $\mu g/m^3$, and averaged only 17 $\mu g/m^3$. Similar low levels were recorded for the same period at the Ministry's monitoring site in Atikokan.

SUMMARY AND DISCUSSION

Pre-operational vegetation and soil sampling in 1981 confirmed the presence of residual arsenic and iron contamination near Ontario Hydro's Atikokan generating station. Distribution patterns of these elements in white pine bark, lichen, feather moss, and surface soil implicate former iron ore pelletizing plants as the principal contamination sources. While this contamination is expected to persist, we believe that foliage sampling,

snow sampling, and moss exposure studies will readily show any changes in contaminant levels after power generation begins.

Because evaluation of an undisturbed ecosystem at Atikokan is not possible, and because effects of power plant emissions are expected to be very subtle, we propose to broaden our future studies with the following additional work.

(a) Calculation of "Enrichment Factors" (EF)

Often, there is considerable natural variation in element levels in vegetation from site to site. To remove this effect, we will calculate enrichment factors for element concentrations in vegetation, based on the elemental composition of soil at each sampling location. In the past, rare earth elements, as well as iron and aluminum, have been used as the soil indicator element (3). We propose using titanium, because it can be accurately analysed and is not actively taken up by plants from soil. Comparing the level of any element to titanium provides a set of ratios which measure elemental enrichment over local soil. Ratios in vegetation exceeding those in soil indicate an ongoing enrichment process for the element examined if, for example, they differ before and after operation of the generating station. The calculation is performed as follows:

$$EF = \frac{\text{element level in vegetation}}{\text{titanium level in vegetation}} \div \frac{\text{element level in soil}}{\text{titanium level in soil}}$$

(b) Stable Sulphur Isotope Ratios (S^{34}/S^{32})

The analysis of S^{34}/S^{32} ratios has been used successfully as an environmental tracer of airborne sulphur in studies in Alberta (4, 5) and Minnesota (6). In the Minnesota study, increases in sulphur in vegetation around a coal-fired power plant were shown, through use of S^{34} tracer, to be due to power plant emissions. The Atikokan generating station will be burning a type of fuel very similar to that used at the Minnesota plant. A comparison of current S^{34}/S^{32} ratios

with future ratios in soils, vegetation, and snow from the same locations should provide another useful tool to assess emission effects.

ACKNOWLEDGEMENT

We wish to thank Ontario Hydro for providing air quality monitoring data from their Atikokan network.

REFERENCES

1. Ontario Ministry of the Environment. 1983. Field investigation procedures manual. Phytotoxicology Section, Air Resources Branch.

2. Goodman, G. T. and T. M. Roberts. 1971. Plants and soils as indicators of metals in the air. Nature 231:287-292.

3. O'Toole, J. J., T. E. Wessels and K. L. Malaby. 1979. Trace element levels and their enrichment processes in terrestrial vegetation. International Symposium, "Stress in Plants", Los Angeles, California, November 7-9, 1979.

4. Krause, H. R. and J. W. Case. 1981. Sulphur isotope ratios in water, air, soil and vegetation near Teepee Creek gas plant, Alberta. Water, Air and Soil Pollution. 15:11-28.

5. Legge, A. H. et al. 1981. Sulphur gas emissions in the boreal forest: The West Whitecourt case study. Water, Air and Soil Pollution. 15:77-85.

6. Krupa, Sagar V. 1981. The effects of dry deposition components of acidic precipitation on vegetation. University of Minnesota, St. Paul, Minnesota.

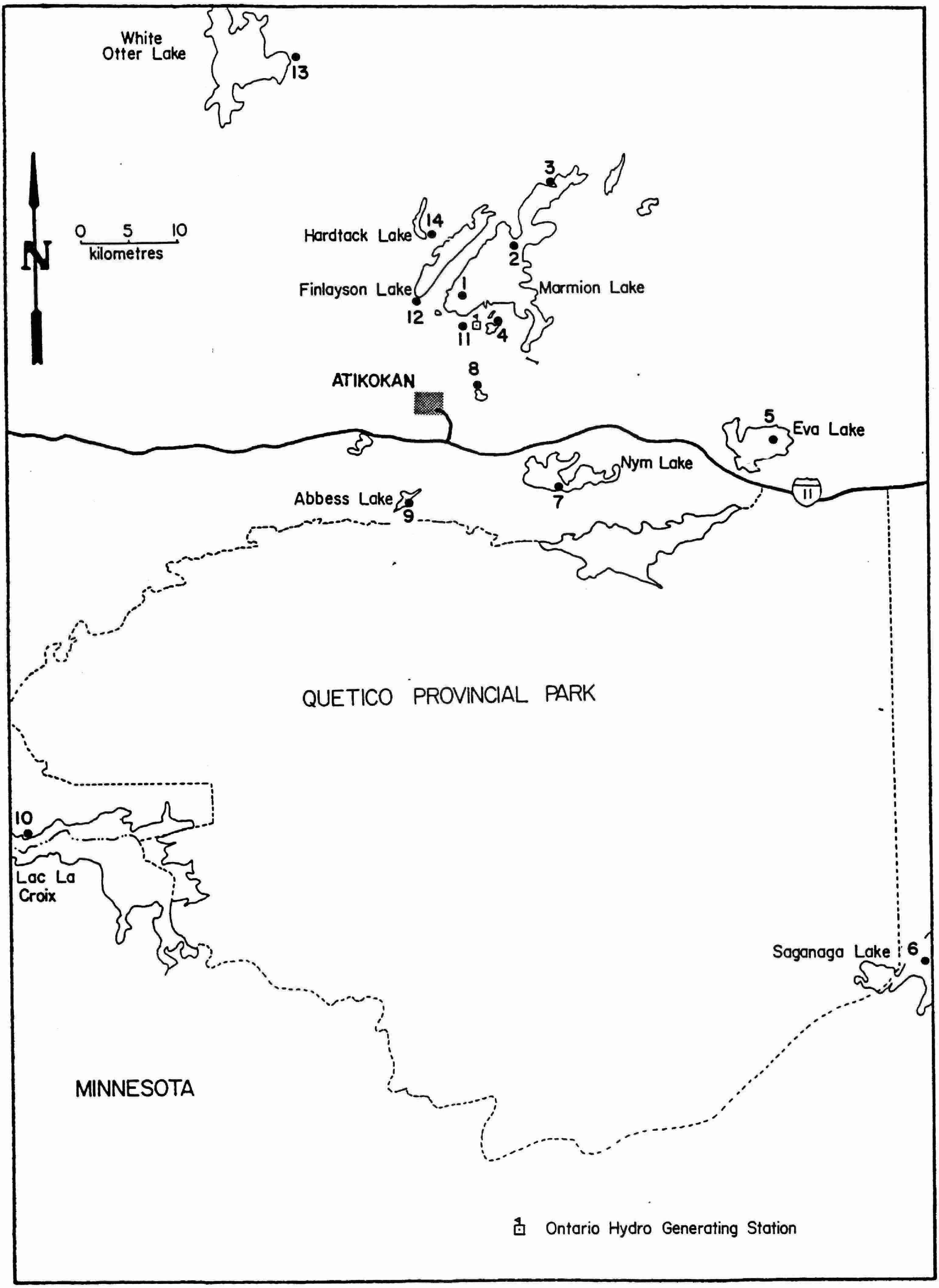

Figure I. Vegetation and soil sampling sites, Atikokan, 1981.

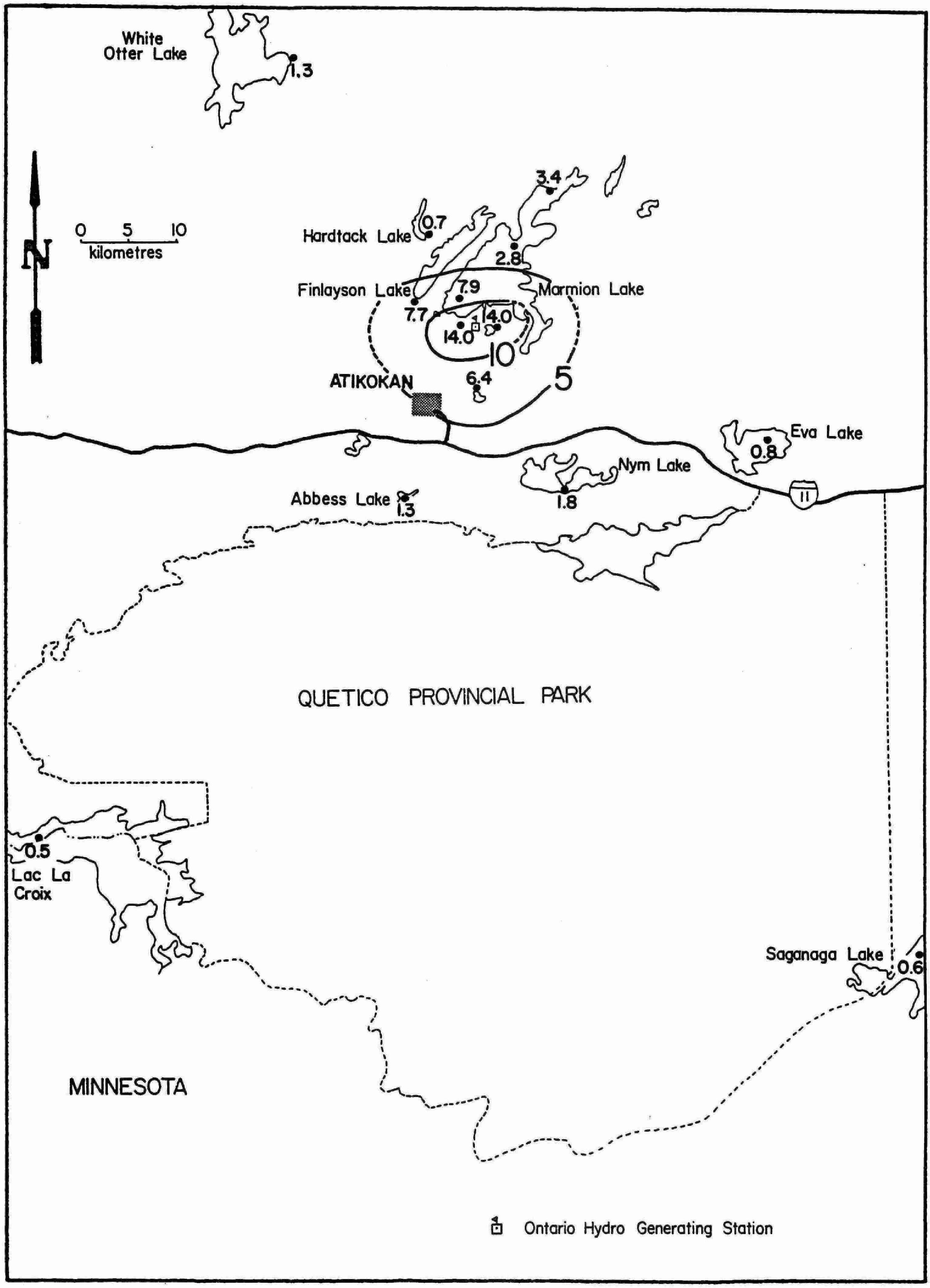

Figure 2. Levels of arsenic (μg/g, dry weight) in Pleurozium, Atikokan, 1981.

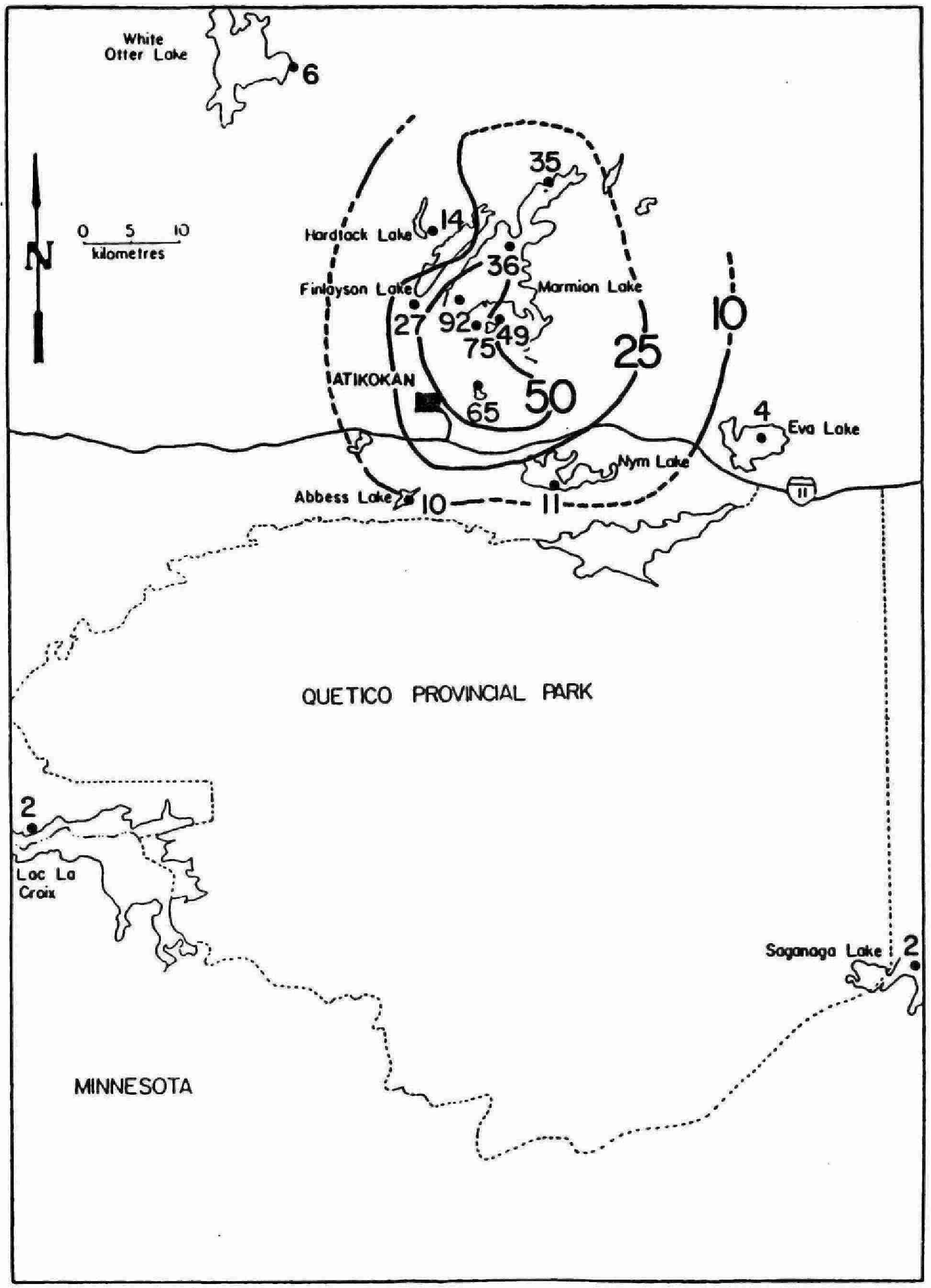

Figure 3a. Arsenic (ug/g) in soil (0-1 cm), Atikokan, 1981.

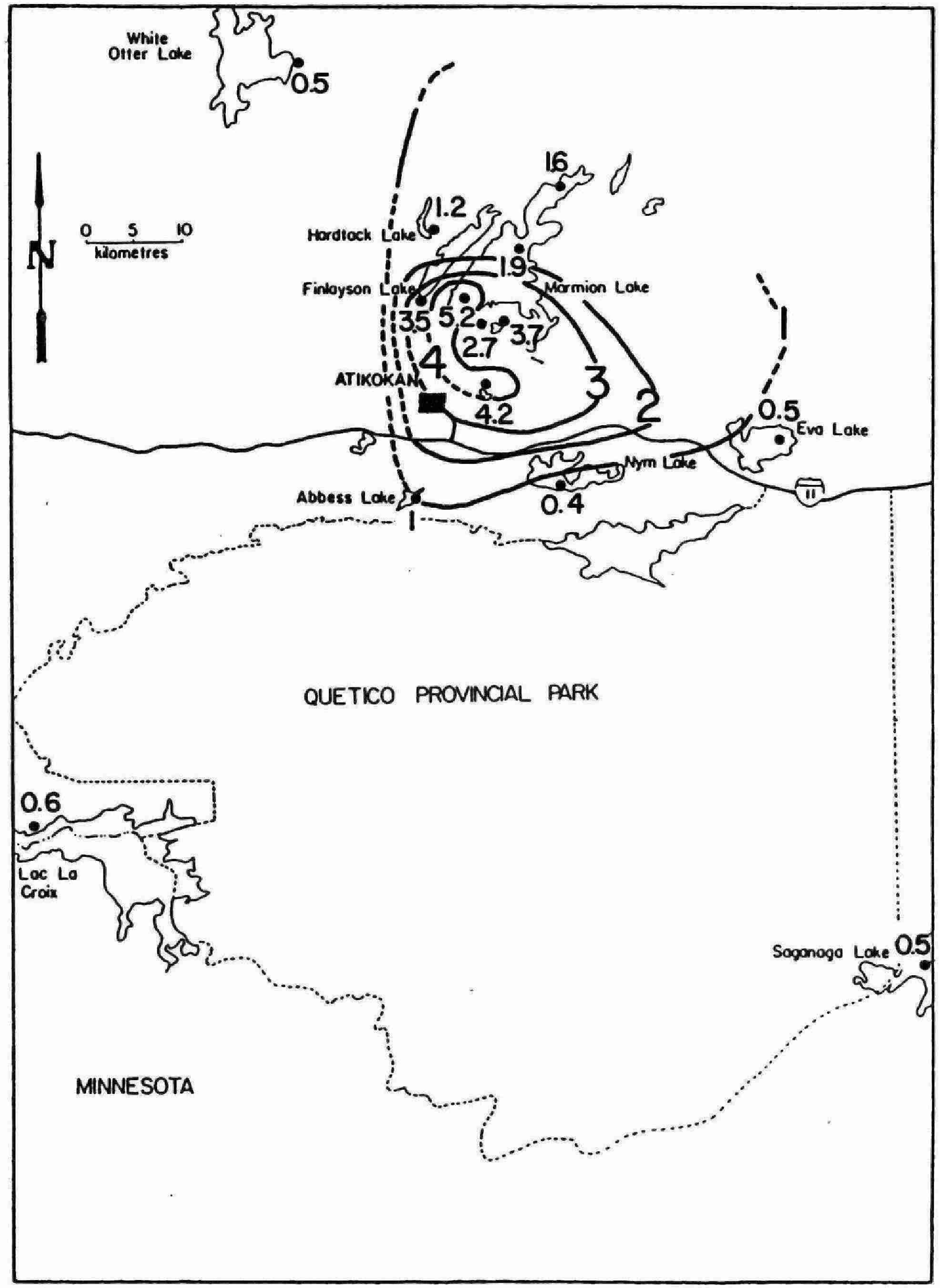

Figure 3b. Iron (%) in soil (0-1 cm), Atikokan, 1981.

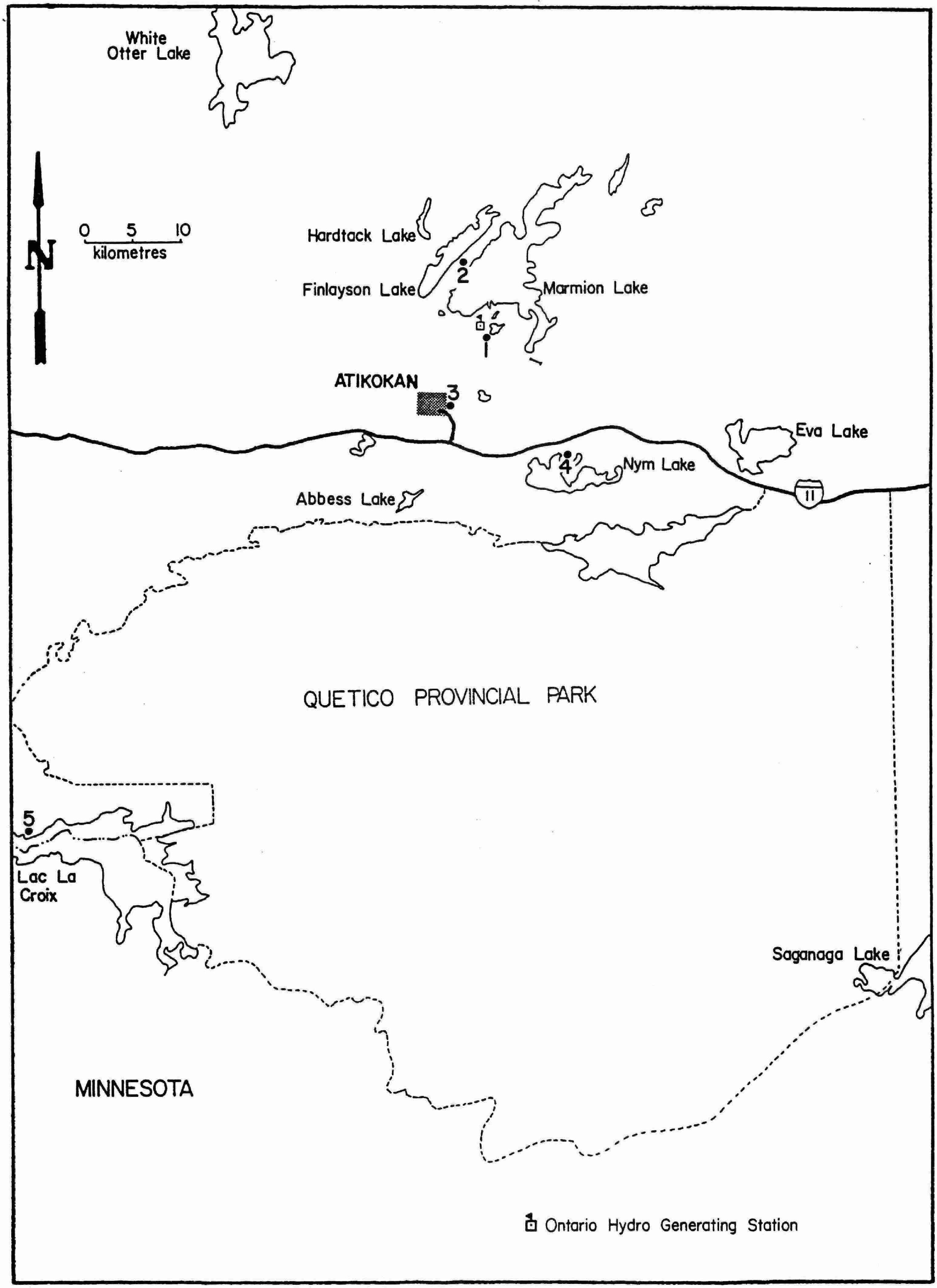

Figure 4. Air quality monitoring sites, Atikokan, 1981.

TABLE 1. Concentrations of selected elements in foliage of white pine (current year and one-year-old), white birch, beaked hazel, mountain maple and willow, and in white pine bark, 1981. All values are in µg/g, dry weight, except chloride and sulphur, which are in %, dry weight.

Plant species		Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Na	Ni	Pb	Zn	Cl	S	F
White pine (current)	mean	147	0.12	0.6	2.6	3.8	66	0.02	219	25	3.9	3	35	0.10	0.10	8
	S.D.[a]	45	0.06	0.4	1.0	1.0	25	0.02	112	0	2.7	1	13	0.00	0.00	4
	high	220	0.30	2.0	5.0	5.5	130	0.08	410	25	11.0	6	64	0.10	0.10	14
	low	60	<0.10	<0.5	<2.0	2.0	36	0.01	70	<25	<2.0	<3	19	<0.10	0.10	3
White pine (1-yr.-old)	mean	436	0.42	0.6	3.2	2.7	212	0.04	386	26	2.8	3	44	0.10	0.10	8
	S.D.	311	0.41	0.2	2.5	0.6	114	0.02	243	3	1.6	0	17	0.00	0.00	4
	high	1500	1.50	1.0	11.0	3.5	490	0.09	870	36	7.0	3	76	0.10	0.10	19
	low	260	<0.10	<0.5	2.0	1.5	100	0.02	98	<25	<2.0	<3	19	<0.10	0.10	<3
White birch	mean	55	0.33	1.1	2.3	5.0	103	0.02	790	25	2.7	3	122	0.10	0.10	8
	S.D.	27	0.57	0.6	0.7	0.9	30	0.01	463	0	1.2	0	65	0.00	0.00	4
	high	120	2.30	2.0	4.5	7.0	160	0.05	1600	26	5.5	5	270	0.10	0.10	12
	low	25	<0.10	<0.5	<2.0	4.0	50	<0.01	80	25	<2.0	<3	24	<0.10	0.10	<3
Beaked hazel	mean	121	0.18	0.6	2.0	6.3	129	0.02	1720	25	2.0	4	15	0.10	0.10	5
	S.D.	51	0.08	0.2	0	0.9	51	0.01	542	0	0	1	6	0.00	0.00	3
	high	180	0.30	1.0	2.0	7.5	230	0.04	2600	25	2.0	5	24	0.10	0.10	10
	low	45	<0.10	<0.5	<2.0	6.0	95	0.01	1100	25	<2.0	<3	9	<0.10	0.10	<3
Mountain maple	mean	59	0.23	0.9	2.8	7.3	125	0.03	621	25	2.1	4	33	0.11	0.13	7
	S.D.	28	0.20	0.6	1.4	2.1	39	0.03	338	0	0.2	2	11	0.04	0.05	4
	high	100	0.70	2.0	6.0	11.0	170	0.09	1000	25	2.5	9	54	0.20	0.20	15
	low	15	<0.10	<0.5	<2.0	5.0	62	0.01	35	<25	<2.0	<3	19	0.10	0.10	<3

TABLE 1. (Continued.)

Plant Species		Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Na	Ni	Pb	Zn	Cl	S	F
Willow	mean	69	0.47	1.3	3.0	5.4	138	0.03	257	26	4.9	5	64	0.10	0.22	6
	S.D.	55	0.76	0.7	2.1	1.4	47	0.02	189	1	3.4	4	54	0.00	0.07	4
	high	175	2.40	2.5	8.0	7.5	250	0.08	620	28	12.0	15	180	0.10	0.30	13
	low	15	<0.10	<0.5	<2.0	3.5	83	0.01	42	<25	<2.0	<3	25	<0.10	0.10	<3
White pine bark	mean	392	2.91	0.6	2.9	3.5	1225	0.08	56	30	2.9	6	28	0.10	0.10	11
	S.D.	179	3.70	0.3	1.7	1.4	1590	0.04	34	9	1.6	4	11	0.00	0.00	6
	high	840	12.0	1.5	6.5	6.5	4800	0.20	130	50	7.5	16	51	0.10	0.10	30
	low	225	<0.10	<0.5	<2.0	2.0	280	0.03	22	<25	<2.0	<3	13	<0.10	<0.10	3
Normal background (foliage only)		<400	<5.0	<3.0	<10.0	<30.0	<800	<0.10	<500	<600	<15	<50	<200			<35

[a]Standard deviation of mean.

TABLE 2. Levels of arsenic and iron (µg/g, dry weight) in white pine bark, feather moss and Umbilicaria lichen, Atikokan, 1981.

Site	White pine bark		Feather moss		Umbilicaria lichen	
	Arsenic	Iron	Arsenic	Iron	Arsenic	Iron
1	12.0	4700	7.8	4200	14.0	13300
2	1.6	780	2.8	1700	12.0	4500
3	1.5	770	3.4	1800	3.8	1900
4	9.5	4800	14.0	9800	15.0	11200
5	0.2	280	0.8	1100	2.2	2000
6	<0.1	310	0.6	760	0.7	970
7	0.8	360	1.8	1600	4.3	2600
8	4.9	2100	6.4	3800	6.5	4000
9	0.3	250	1.3	1800	4.3	2900
10	0.1	330	0.5	1800	1.0	2300
11	3.7	530	14.0	5500	29.0	4100
12	3.9	1500	7.7	5700	7.2	3900
13	0.3	280	1.3	1200		
14	1.9	390	0.7	800	3.9	3300
Normal background			<5	<800		

TABLE 3. Concentrations of selected elements in *Sphagnum* moss[a] exposed from May 25 to July 29, 1981. All values are in µg/g, dry weight, except those for chloride and sulphur, which are in %.

Mean and range	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Na	Ni	Pb	Zn	Cl	S	F
Mean	1170	0.38	0.8	4.1	5.4	1270	0.13	193	144	3.1	10	39	0.10	0.10	22
S.D.[b]	184	0.20	0.6	2.4	1.0	262	0.10	48	52	1.2	3	5	0.00	0.00	6
High	1500	0.70	2.5	7.5	6.5	1700	0.40	280	240	6.0	13	6	0.10	0.10	32
Low	860	<0.10	<0.5	<2.0	3.0	950	0.05	140	80	<2.0	5	30	<0.10	<0.10	12

[a] Samples from two sites were lost in the field.
[b] Standard deviation of the mean.

TABLE 4. Levels of selected elements and pH in three depths of soil, Atikokan, 1981. All values are in μg/g, dry weight, except aluminum, calcium, iron, potasium and magnesium, which are in %, dry weight.

		Al	As	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg	Mn	Na	Ni	P	Pb	Zn	F	Cl	S	pH
Soil (0-1 cm)	mean	0.7	30.4	0.8	1.8	38	70	2.0	0.25	0.14	0.24	852	88	15	0.7	57	82	101	<0.1	0.13	4.3
	S.D.[a]	0.4	29.7	0.2	0.9	37	122	1.5	0.11	0.04	0.22	743	51	12	0.2	16	35	84	0.0	0.05	0.5
	high	1.8	92.0	1.0	4.0	140	480	5.2	0.41	0.23	1.00	2200	230	41	1.3	87	150	360	0.1	0.27	5.4
	low	0.3	2.0	0.5	0.5	9	14	0.5	0.02	0.09	0.11	88	38	1	0.1	24	33	25	<0.1	<0.1	3.5
Soil (1-2 cm)	mean	1.2	9.9	0.5	1.4	31	29	1.6	0.13	0.11	0.28	296	133	11	0.6	31	43	114	<0.1	0.09	3.8
	S.D.	0.4	9.7	0.2	0.8	30	28	1.0	0.08	0.04	0.26	303	71	10	0.2	14	20	92	0.0	0.05	0.4
	high	1.9	33.0	0.8	3.0	120	120	4.3	0.32	0.19	1.10	980	280	43	1.0	52	79	380	<0.1	0.20	4.9
	low	0.5	1.6	0.3	0.5	6	11	0.5	0.03	0.05	0.09	27	12	1	0.3	8	18	32	<0.1	<0.10	3.4
Soil (2-5 cm)	mean	1.4	3.5	0.3	1.3	33	31	1.6	0.05	0.09	0.33	139	165	17	0.4	11	36	146	<0.1	0.05	4.1
	S.D.	0.7	2.3	0.1	1.0	26	55	1.1	0.03	0.04	0.26	219	55	16	0.3	6	21	109	0.0	0.03	0.6
	high	2.6	8.7	0.6	3.5	90	220	4.6	0.15	0.15	1.10	890	270	66	0.8	25	88	450	0.1	0.12	5.6
	low	0.5	0.5	0.1	0.5	1	8	0.3	0.02	0.03	0.09	34	87	2	0.1	2	6	25	<0.1	<0.10	3.4
Normal background			<20		<5	<75	<100		<0.30			<1500		<70		<150	<300				

[a]Standard deviation of mean.

TABLE 5. Levels of arsenic (μg/g, dry weight) and iron (%, dry weight) in three depths of soil, Atikokan, 1981.

Site	Soil (0-1 cm)		Soil (1-2 cm)		Soil (2-5 cm)	
	As	Fe	As	Fe	As	Fe
1	92	5.2	24	2.0	4	1.4
2	36	1.9	4	2.2	7	1.3
3	35	1.6	8	1.6	4	2.8
4	49	3.7	22	2.5	6	1.0
5	4	0.5	3	0.5	<1	0.7
6	2	0.5	2	0.5	2	0.5
7	11	1.0	4	0.8	3	2.4
8	65	4.2	12	1.6	5	1.6
9	10	1.0	5	1.9	4	2.4
10	2	0.6	2	0.5	<1	2.9
11	75	2.7	33	1.6	4	1.4
12	27	3.5	10	4.3	9	4.6
13	6	0.5	4	0.7	1	1.0
14	14	1.2	10	1.1	2	1.6
Normal background	<25		<25		<25	

TABLE 6. Summary of sulphur dioxide concentrations (ppb) at Ontario Hydro monitoring sites, Atikokan, May-December, 1981.

Station		Percent valid data	Monthly average	Maximum reading	
				1-hour	24-hour
1	Switchyard	74.3	0.98	14.0	5.8
2	Finlayson Lake	0			
3	Atikokan	55.9	0.95	10.0	6.6
4	Nym Lake	96.6	0.45	7.9	4.5
5	Lac La Croix	95.7	0.65	32.0	7.2

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